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Lighting villages at the end of the line with geothermal energy in eastern Baringo lowlands, Kenya – Steps towards reaching the millennium development goals (MDGs)

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ABSTRACT

Access to modern energy services is key to economic development and progress towards millennium development goals (MDGs). Yet only 20% of Kenyan population of which 5% are rural residents have access to electricity. The study focuses on East Pokot and Marigat Districts, commonly known as Baringo eastern lowlands within the Kenyan Rift Valley. The two districts lie at the end of a 190 km high voltage line from Lessos substation in Nandi District, which traverses rough terrain and serving major towns before reaching the study area. Extension of the line has also been hampered by several barriers discussed in this paper. Consequently, less than 1% of the households in small trading centres have access to electricity with an average consumption of 120 kWh/month and 500 kWh/month per utility in the commercial sector. About 60–70% of the local population live below the poverty line and micro, small and medium enterprises are not well developed due to inadequate supply of electricity and poverty. The area lies within undeveloped six geothermal prospects between Lake Bogoria and Silali with an estimated resource potential of about 2700 MWe. Since the current government focus is to develop the geothermal resources in the area, the study assess the overall impact of the planned development in contributing towards the attainment of the millennium development goals (MDGs).

Contents

Abbreviations: AGECC, Advisory Group on Energy and Climate Change; ASAL, arid and semi arid lands; CDM, clean development mechanism; FGM, female genital mutilation; GoK, Government of Kenya; KES, Kenya shilling; KMC, Kenya Meat Commission; KPLC, Kenya Power and Lighting Co. Ltd.; LED, light emitting diodes; MWe, megawatt electric; UN, United Nations; UNEP, United Nations Environment Program; IAEA, International Atomic Energy Agency.

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1. Introduction

1.1. Millennium development goals (MDGs) and energy

The United Nations (UN) member states adopted the Millennium declaration and the Millennium development goals (MDGs) in September 2000, agreeing on 8 measurable goals and time bound targets to reduce extreme poverty, hunger, illiteracy, gender inequality, disease, and environmental degradation by 2015 [1]. Despite this, lack of access to modern energy services and recurrent impacts of climate change have continued to undermine progress towards the MDGs especially in sub-Saharan Africa.

Though energy is not mentioned in the 8 goals, the provision of modern energy services is recognised as a critical foundation for sustainable development [2–4].

Access to modern energy services can have significant impact on aspects of the MDGs by accelerating economic development through industrial growth and increasing access to global markets and trade, social development by meeting basic human needs of nutrition, warmth, and lighting as well as improvement in education and public health. It can also protect local and global environment by curbing deforestation and loss of carbon sinks and generally reducing emissions from fossil fuels if derived from renewable energy sources [5]. To achieve this, energy should be accessible and affordable to the people who need it.

1.2. Access to electricity and affordability

The International Atomic Energy Agency (IAEA) describes accessibility as share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy. Affordability is defined as share of household income spent on fuel and electricity (International Atomic Energy Agency (IAEA)) [6].

According to Advisory Group on Energy and Climate Change (AGECC) [7], electricity is considered affordable if the cost to end user is compatible with their income levels and no higher than the cost of traditional fuels and should not be more than reasonable fraction of their income (10–20%).

Accessibility and affordability are clear indicators of social and national economic development in any given society thus increasing energy consumption is linked to economic growth.

1.3. Access to electricity in Kenya

Kenya is still predominantly a rural country with over 80% of the population living in the rural areas. About 20% of the total population of Kenya and only about 5% of the rural population have access to electricity. Despite major investments in the rural electrification program by the government, population growth exceeds the rate of rural connections. Outages either due to drought or lack of system maintenance as well as voltage fluctuations have resulted in unreliable service causing economic losses [8,9].

The ability to meet the demand is also limited by low economic investment in energy infrastructure in rural areas making biomass the main source of energy for cooking, lighting and other social and economic services for the rural population. Dependency on non-commercial biofuels, collected by women and children, has come at a heavy price on the environment and health of women and young girls who spend long hours in smoky kitchens [10] (Chengole, personal communication, 2010; Obiero, personal communication, 2010).

Recent institutional and legal reforms in the power sector are expected to accelerate electrification using both centralised and decentralized systems. The decentralised systems carried out by the rural electrification authority (REA) are mostly geared towards solar-powered generators for secondary schools and public institutions in marginalised arid and semi arid areas of the country. Enhanced exploratory work on geothermal resources is ongoing and will increase access to modern energy services for economic, social and environmental purposes nationally and in the most marginalised areas in the northern part of the country where most of the unexploited energy resources occur.

1.4. Impact of drought on energy security and access in Kenya

Due to the current high dependency on hydropower, impacts of droughts and floods are directly linked to energy security in Kenya. Recurrent floods in Kenya have led to heavy siltation of reservoirs leading to loss of storage for hydropower generation. Droughts which have become intense in the last decade cause drastic water reduction in the reservoirs leading to induced load shedding. The impact of drought on hydropower production was very significant during the prolonged 1999/2001 drought and the preceding droughts 2006–2009, the worst year in Kenyan drought history being the 2008/2009. These led to power rationing and the engagement of emergency power providers (EPPs) (Aggreko PLC International) that provided up to 290 MWe in 2009 (Internal communication with KenGen). Further, the dependence on emergency power and general impacts of climate change in Kenya have diverted financial resource that would have been used in the attainment of MDGs and increased vulnerability and poverty through drought related losses.

The focus on investment in geothermal and wind energy will reduce dependency on imported fuels, lower the per unit cost of power hence making it more affordable, reduce CO_2 emissions resulting from fossil fuels from emergency power and provide high quality power. Scaling up access to modern energy services using geothermal energy is crucial for poverty reduction and can speed up progress for the UN Millennium development goals (MDGs) and dealing with climate change challenges.

1.5. Objectives and structure of the paper

The objective of the study was to project the potential impact of planned geothermal development on the millennium development goals in marginalised Marigat and East Pokot Districts. The two districts fall within Lake Bogoria and Silali prospects with an estimated undeveloped resource potential of about 2700 MWe [11]. Geothermal is therefore the most feasible, accessible and indigenous mode of power generation in the study area compared to the rest. The study will also assess the status of electrification, the current barriers to access and affordability of electricity in the region.

A mix of field study, personal interviews and literature review is employed in the study. Section 2 gives a description of the study area, current and potential uses of electricity, present barrier to electrification, and why geothermal energy is the focus of the study. Section 3 discusses potential contribution of the geothermal development on MDGs and Section 4 contains discussions and conclusion.

2. Study area

Administratively, the study area covers the new Marigat and East Pokot districts which were curved out of the greater Baringo District. Marigat residents are predominantly agro-pastoralist while East Pokots are pure pastoralists. The area is falls with arid and semi arid lands (ASAL) in the northern part of the central rift, with temperatures of above 32 °C and average annual rainfall <600 mm [12]. Infrastructure is not well developed making most of the areas inaccessible and highly marginalised.

2.1. Energy resources in the study area

Energy consumption in the study area is dominated by wood fuel which constitutes about 99% of energy used for cooking, lighting and other socioeconomic activities in the remote parts of the two districts, while kerosene and others constitute $\leq$0.5% (Obiero, personal communication, 2010). Kerosene is only used for lighting in households closer to market centres.

Table 1
Estimated geothermal resource potential.

Geothermal field	Estimated resource potential
Korossi	450
Chepchuk	100
Paka	500
Silali	1250
Bogoria	200
Baringo	200
Total	2700

Source: Ministry of Energy, 2010.

Despite the high potential in wind, solar and geothermal resources, their utilization for modern energy services largely remain untapped due to low investment of energy infrastructure in the region. The use of biogas from animal waste in homes and school cooking programs has also not been exploited. *Jatropha* farming for biodiesel production is still at its initial stage of seedling production.

Solar energy is used to a limited extent in boarding schools, churches, remote offices of Non-Governmental Organizations (NGOs) and public offices for lighting, borehole/spring water pumping, fencing to control illegal grazing (RAE Trust Lemuye community in East Pokot) and beeswax melting. Sun drying of crops and fish products is the most common. The use of wind energy is limited to the highlands east of the study area and mainly used for water pumping in a few places. Solar and wind have made insignificant difference in lighting and water pumping despite due to the cost of installation, reliability, availability and affordability. Their uses are also limited to institutions and community projects. Consequently, diesel generators are becoming the preferred alternative for water pumping and lighting purposes.

2.1.1. Geothermal resources

The government is planning to accelerate geothermal development for electricity production in the area which remains untapped despite the potential. Detailed exploration and resource potential assessment have been done (Table 1).

The development of the geothermal resources in remote parts of the study area which were considered in-accessible will bring energy closer to the local community and facilities. The advantage of using geothermal energy lies is fact that it can be installed in modular units which are transportable and also provide flexibility in demand based capacity expansion. Geothermal energy will also bring stable, reliable and quality power in the region if accompanied with the right incentives that will enable access and affordability and contribute to general progress towards the MDGs. Geothermal energy is also considered clean and renewable if sustainably used [4].

This paper mainly focuses on the impact of electrification on the MDGs while details of the impact of direct or low temperature utilization on adaptation to impact of climate change are discussed in Ogola [13].

2.2. Status of electrification in the study area[1]

Marigat and East Pokot are currently served from the Marigat 1.5MVA 33/11 kV substation. The electricity is transmitted from the 132/33 kV Lessos substation through a 33 kV power line which

[1] Information is based on March–April 2010 data and it subject to change depending on the rate of accelerated geothermal development in the next two to three years.

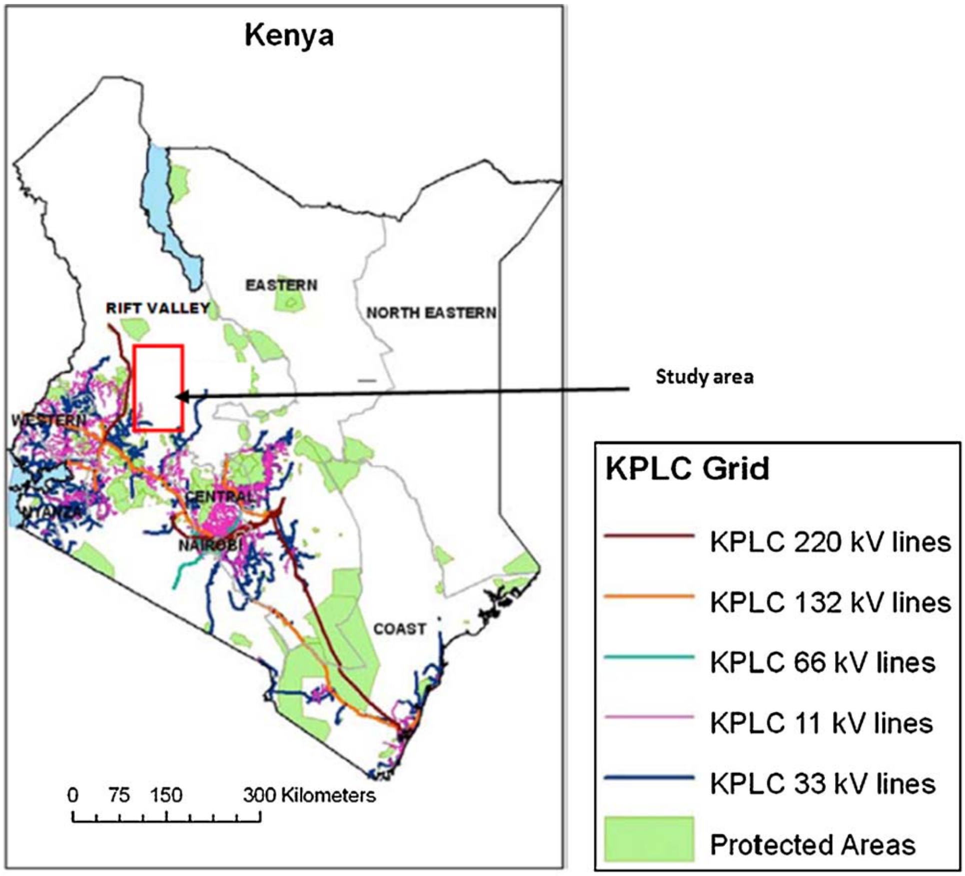

Fig. 1. Existing grid and the location of the study area.

Source: modified from KPLC 2007.

runs for 190 km on steep terrain through Burnt Forest, the Kerio Valley to Kabarnet and finally to the Marigat 33/11 kV substation. The electricity is used in major towns along the way before it reaches Marigat, which technically puts the study area at the end of an overstretch power line with poor and unreliable quality. From the Marigat substation, 11 kV line distributes electricity to Nginyang' and Chemolingot in East Pokot (where it arrived for first time in 2009). The distribution line runs from Nginyang' to Chemolingot for a distance of 55 km without being utilised by the pastoralists (Agesa, personal communications, 2010). The homes in the area are sparsely populated and temporary structures made of wood/sticks and mud.

Another line runs from Marigat to Lake Bogoria along the southern margins of the study area and was constructed in 1992 following the commissioning of Lake Bogoria Spa Resort. In the east, parts of Mukutani are served with electricity from Laikipia, which is also at the end of the line. The vast part of the study area in East Pokot and south of Lake Baringo on the Njemps flats to Perkerra irrigation scheme remains with no access to electricity (see Fig. 1). Plans to accelerate network expansion by the new transmission company to meet the planned geothermal development and wind from Turkana are underway.

2.3. Current electricity use in domestic and commercial sector

Majority of electricity users are concentrated in Marigat market since it is the main centre from which connections are made. Out of the 644 customers connected, 32% are domestic users while 68% are commercial users. Therefore, only about 207 households have been connected which is less than 1% of the households in the study area. The average monthly consumption per household is estimated at 120 kWh/month (Table 2). These are mostly government employees and other institution employees living in small centres with electricity connection hence no impact on the local community households. The estimates were made from the total consumption of all customers.

Table 2
Average electricity consumption in the domestic and commercial sectors.

Category (purpose for consumption)	% of customers	Average monthly consumption (kWh)
Domestic (residential)	32	120
Commercial (non domestic)	68	500

Source: Kenya Power & Lighting Co. Ltd., 2010 (Kabarnet Office).

Most of the local people either complete their chores before dark or use wood fuel, candles or kerosene lamps for lighting. Transporting kerosene to the remote areas is expensive and the use of kerosene and wood fuel is harmful to health and environment (Obiero, personal communication, 2010). The use of electricity in the commercial sector is mostly for services, e.g. hotels and restaurants, retail shops, posho mills, wielding and in institutions like offices, schools, hospitals, churches but at a very small scale (see Fig. 2). The general monthly average consumption in this sector is given as 500 kWh for 438 customers. Hotels and restaurants consume 40% of the electricity in the commercial sector with a customer base of 0.5% while retail shops and kiosks in the market centres only consume 13% and constitute 50% of the customers in the commercial sector (Fig. 2).

There are no manufacturing industries since cotton ginnery, fish processing plant and the wine-making factory closed down in the

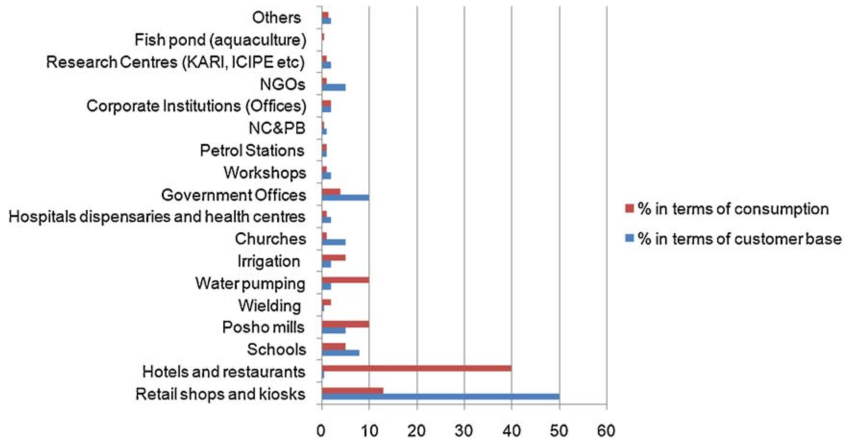

Fig. 2. The categorization of the commercial uses of electricity.

Source: KPLC Office Kabarnet.

1980s. Most of these factories used diesel to run their processes. The new Baringo bio-enterprise, which was recently closed down due to management problems processed aloe sap using fuel-wood. The factory is not connected to the distribution line despite its close proximity to one because of what they termed as prohibitive costs and unreliable electricity. Artisanal industry (*known as jua kali in Swahili*), e.g. carpentry, tailoring, blacksmith, barber shops, grocery kiosks that require energy like in most parts of rural Kenya are not well developed limiting self employment opportunities. A lot of untapped potential for use of low to high enthalpy geothermal resources in industrial development and tourism industry exists.

The development of geothermal resources will bring electricity closer to the region and provide clean and stable power is likely to spin off economic development if accompanied by other sectoral and infrastructural development.

2.4. Potential for use of electricity in the study area

Advisory Group on Energy and Climate Change (AGECC) [7] categorizes levels of energy needs into basic human needs, productive uses and modern society needs (Fig. 3).

The basic human needs can be met by either small scale renewable energy technologies, off grid or mini grid connectivity or main grid. As energy needs progresses, more stable and reliable network connection is needed for to maintain productive uses and modern society needs.

2.4.1. Potential for use in homes

The most basic need for electricity use in the rural home is for lighting. The average domestic consumption in the study area is 120 kWh per household using electricity (see Section 2.3 and Table 2). Most of the households are located in the trading centres where employed households reside.

Unlike the 120 kWh consumed per month by the working households located in the trading centres, the rural homes would only require a single bulb for lighting. A household using a single bulb of 100 W of electricity for lighting for 3 h per day in the evening will consume 9 kWh a month or half of that if they are using a 50 W bulb and a quarter if using a 25 W light-emitting diodes (LED) bulb. Based on the above assumption, at least 20,000 rural households in Marigat and East Pokot each using the traditional incandescent light bulbs of 100 W for lighting for 3 h/day, will require 180,000 kWh/month, 90,000 kWh/month (90 MWh/month) for 50 W bulb and 45,000 kWh/month (45 MWh/month) for 25 W bulb. Though the LED bulbs are more costly, they consume less; have high luminance, last longer and therefore cost effective. In the fiscal year 2009/2010, the Kenya government through Kenya Power and lighting company launched a campaign to replace the incandescent light bulbs with more energy efficient bulbs. The lighting can be achieved subject to upgrading the houses from mud thatched to at least corrugated iron sheet as explained in Section 2.5.

10,000 households using 100 W bulbs for lighting can be served by 1 MW plant based on estimates from Latin America, e.g. Nicaragua, the Caribbean and Philippines [14]. Based on these estimates, a <5 MW geothermal power plant can be used in meeting basic human needs by providing electricity for lighting at home, in school and offices with the current population in the study area. Additional energy would be required for productive uses in agriculture, water pumping, etc. and for modern energy services such as for cooking, heating, cooling, ironing, etc.

Electricity connection in the homes will lead to improved standards of living as most people will strive to upgrade their houses to better structures, gradually purchase mobile phones, radios and television sets. The rate of rural electrification will also be accelerated due to geothermal development activities and new suppliers and project workers.

2.4.2. Potential for electricity use in public service sector

In the health sector, electricity will play an important role in storage of life saving vaccines and other medical supplies which are sensitive to temperature fluctuations. Electricity is also needed for better medical equipments that require reliable power supply, which are presently not available in the study area. Better medical equipment and electricity is important in retaining trained medical staff in the region.

Provision of electrification in schools makes studying at night and in early morning possible and also boosts access to the Internet, improving the quality of education giving them an equal chance to children in urban areas. The potential for use in institution offices also increase working hours when necessary and improve data storage from paper to electronic and electronic communication in general. Summary of average energy used in rural institutions is given in Table 3 [15] and can give general indications of electricity requirements for public and private institutions in the study area.

2.4.3. Potential for small scale business and improved communication

Artisanal industry and micro enterprises in the study area are not well developed and do not exist in some trading centres in the area due to lack of electricity. Electricity will boost small scale

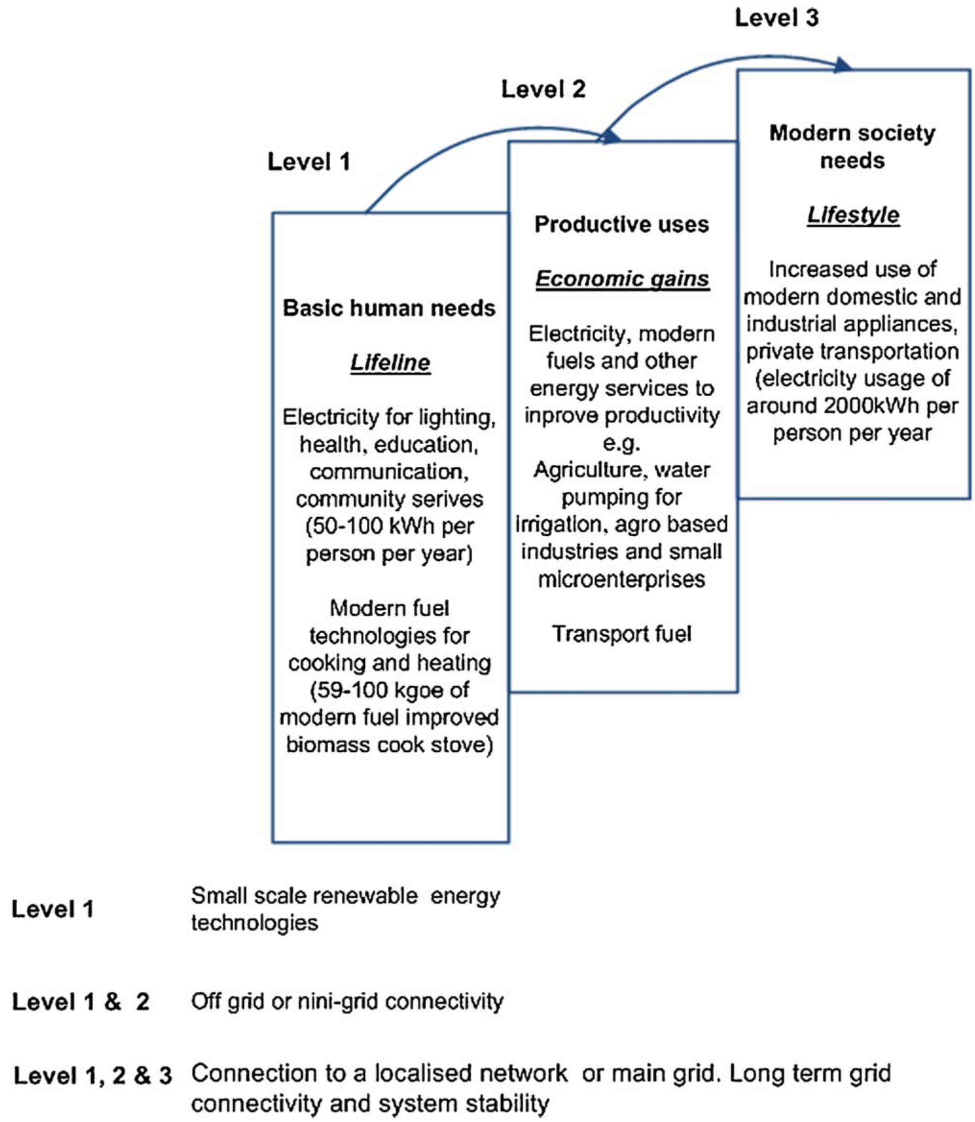

Fig. 3. Incremental levels of access to energy services.

Source: modified from AGECC 2010.

Table 3
Average rural institutional consumption in Kenya.

Basic consumption (kWh/institution/year)	
Clinic	100
Dispensary	141
Health centre	1032
Primary school (day)	305
Secondary school (day)	1071
Boarding school	15,000

Source: Kenya Power & Lighting Co. Ltd., 2007.

businesses like wielding, hair salons, carpentry, battery charging, posho mills, restaurants, provision of internet services, use of mobile phones, access to information through radio and televisions which will in-turn boost the local economy and standard of living.

2.4.4. Electricity use in agricultural production and industrial processes

The use of electricity in dry season water pumping for domestic, livestock and small scale irrigation can alleviate drought related water stress and improve food security and nutritional levels of the local community, refrigeration and lighting for meat processing, fish filleting, milk processing, hospital and veterinary vaccines and mining processes. In additon to these, processes that have been proposed under direct utilization will also require electricity in their production processes [13].

2.5. Current barriers to electrification in the study area

Despite the geothermal and other renewable energy potential in the area, access and affordability to electricity has been marred with challenges.

2.5.1. Poverty

The region has high level of poverty index ranking nationwide with 60–70% of people living below the poverty line each day [16]. The implication of this in relation to access to electricity means that people cannot afford connection fees or construct houses where electricity can be installed. For instance, the vast majority cannot afford the initial connection fee of KES 34,980 (approximately

Fig. 4. Hot weather friendly but not suitable for electricity installation.

USD 448).[2] This fee only applies to customers within a radius of 600 m from a transformer. An assessment of the region indicates that about 1500–2000 potential customers are within this radius and can be connected with existing infrastructure, especially around the small trading centres. The cost of connecting customers or group of customers who are beyond the 600 m radius from existing transformers is huge and demands stretching the high tension power line and installing new transformers. Even where people are within the 600 m reach of transformer, only one out of 100 customers applying for connection may be able to afford it. Affordability is still a challenge even where the Rural Electrification Authority builds power lines at a much cheaper rate of KES 22,400 (USD 287) as opposed to KES 34,980 (USD 448)[3] by KPLC as most households live below the poverty line of USD 1.25 dollar a day.

Connection through 'Umeme Pamoja' directly translated as 'Electricity Together' was designed to enable a group of people to acquire electricity together at an affordable rate. Despite this initiative, the cost is still prohibitive especially due to low income, rough terrain and low population density.

2.5.2. Low population density

The population density in the East Pokot is about 17 persons/km^2 while in Marigat and Mchongoi area is approximately 40 persons/km^2 with the highest population density around the trading centres like Marigat, Chemolingot, Tangulbei and Mchongoi [11]. The sparse population density in the area pushes the cost of power installation up as the distribution line is stretched over long distances only to connect a handful of customers. This also escalates costs for network maintenance. Geothermal energy can be used in providing electricity through small scale decentralised systems or mini grids which can eventually be connected to the national grid and reduce the operation and maintenance costs of the transmission line.

2.5.3. Temporary housing structures

At least >80% of houses are made of sticks and mud and susceptible to floods and termites and hence cannot be wired (Fig. 4). KPLC can install electricity in an improved house using corrugated iron sheet (Fig. 5).

2.5.4. Poor road network and access

There are basically no asphalt roads in the larger part the study area except from Marigat to Bogoria and from Marigat to Lake Baringo at Kampi ya Samaki and Loruk. The total asphalt road within the study area is approximately <50 km and mostly along the boundary and not vast interior of Marigat district. Beyond the asphalt, the gravel roads with no bridges are impassable during and after the rainy season due to degradation by floods. The poor road network has hindered both supply and demand of electricity and overall economic development of the area leading to low income and dependency on livestock economy.

2.5.5. Unfavourable terrain and overstretched power line

Due to the fact that there is no power generation facility in the area (despite high potential in geothermal energy), the distribution line is technically overstretched and cannot adequately supply the entire area under study. The power is sourced about 190 km away and used in major towns before it reaches the area. The line traverses very unfavourable terrain hence vulnerable to chronic breakdowns. As a result, the few customers in the study area (eastern lowlands) have to bear with frequent blackouts as they are at the end of the distribution line.

2.5.6. High maintenance cost due to soil erodibility and termites

The study area is highly susceptible to soil erosion. The high soil erodibility in the few areas under supply causes collapse of power lines due to its inability to hold structures firmly. Additionally wood peckers and termites destroy the wooden poles forcing KPLC to replace them at very frequent time intervals. The best poles for the region would be concrete poles, which are expensive and would escalate the cost of providing electricity. This also results in high cost from vehicle maintenance and repair due to poor roads and vastness of the region (geographical spread of the customers).

[2] People have assets in form of livestock and may not be "poor" but only "food poor". The measure of poverty in the area is relative. Though some people can afford electricity, they are not willing to sell their animals to connect electricity or pay the bills.

[3] The exchange rate of one US dollar to Kenya Shillings was approximately 78 at the time of the study.

Fig. 5. KPLC can install electricity in a corrugated iron sheet house. The house is not suitable for the weather because it gets very hot.

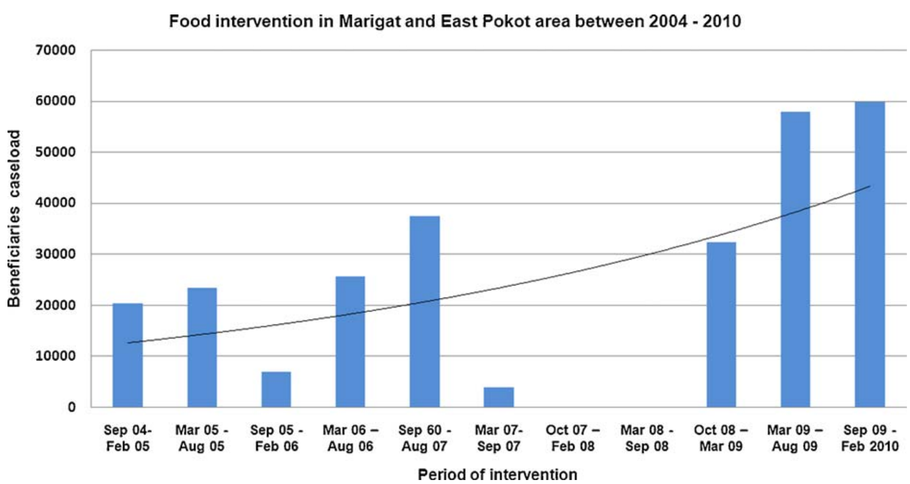

Fig. 6. Food aid intervention in the present Marigat and East Pokot areas from 2004 to 2010.
Data extracted and compiled from the greater Baringo District 2004–2010 food aid intervention (Government of Kenya, 2010).

Consequently, the cost of maintenance surpasses the revenue generated from the region.

3. Impact of geothermal development on the millenium development goals (MDGs)

This section describes the current status of each goal and how geothermal development can assist in meeting the goals.

3.1. Goal 1: eradicate extreme hunger and poverty

3.1.1. Food security and hunger

Food insecurity in the region is mainly caused by poor rainfall leading to crop failure, depressed livestock markets, inadequate pasture and water leading to livestock mortality, migration and conflicts, high food prices, poor infrastructure, poor market access, illiteracy, land degradation, livestock/human diseases, and retrogressive cultural practices. Food scarcity has led to high dependency on food aid which is distributed as food for asset (FFA) or general food distribution (GFD) (Chengole, personal communication, 2010; Atuti, personal communication, 2010).[4]

Fig. 6 shows food aid intervention in the greater Baringo District from 2004 to 2010 [17]. The dependency on food aid has been increasing over time due to factors mentioned above. The figure includes all regions of the greater Baringo district but the study area is defined by Marigat, Mukutani, Mchongoi, Nginyang', Tangulbei and Kolloa with Nginyang' receiving the highest food aid.

Unlike other drought stricken parts of Kenya, the distribution of food aid was started in 2004 after the retirement of former president who provided for the Baringo people during his 24 year tenure as the president of Kenya and Member of Parliament for Baringo Central (Atuti, personal communication, 2010).

Table 4 further shows % of population that required food aid in the study area during the 2008/2009/2010 drought. It is estimated

[4] FFA (Food For Asset). In the past, it was called Food For Work but later changed to Asset because the communities are required to generate communal assets like water pans, canals, in exchange for food.

Table 4
Population requiring food aid in 2009 and 2010. No data was available for Kolloa in 2010.

Division	Population 2009 (based on 1999 population census projections)	% of population requiring food aid 2009	% of population requiring food aid 2010
Mukutani	9178	30–35%	60–65%
Nginyang	35,593	40–45%	60–65%
Kolloa	18,295	40–45%	
Tangulbei	23,805	20%	20–25%
Marigat	32,853	10%	20–25%
Muchongoi	13,536	15%	20–25%

Source: extracted from Government of Kenya 2010.

that between May 2009 and January 2010 about 6000 metric tons (MTS) was distributed to 118,000 beneficiaries in the district [17].

The use of geothermal energy in provision of electricity for food preservation, small scale water pumping for dry season irrigation, greenhouses for commercial crop production and famine relief, value addition of livestock, agricultural products, fisheries resources will improve food security and reduce vulnerability to drought and post harvest losses in a good season [18]. Farming households will have access to grow a second and third crop each year, thus alleviating the impact of drought and dependency on food aid. Both government and private investments are required to achieve this objective. Introduction of alternative diet among the pastoralists due to extended area under irrigation will also reduce malnutrition and child mortality.

3.1.2. Poverty

The region has high level of poverty index ranking nationwide with 60–70% of people living below the poverty line per day [16] and at least 62% of the people are food poor [12]. Poverty levels are volatile and depend on extreme weather events and conflicts. In years of crisis, the levels in Marigat can rise to 67% and East Pokot to about 70–73% (Chengole, personal communication, 2010).

Effective poverty reduction should be tied to the livestock economy which is the means of survival. This can be achieved by establishing Kenya Meat Commission (KMC) satellite stations or abattoirs in the study area due to improved access to electricity in order to provide an outlet for selling livestock throughout the year and much faster in the early stages of a drought as well as reducing dependency on food aid. The development of livestock infrastructure within reasonable distance will depend on access to energy services and improvement of road and water facilities. Enhanced vaccination will also reduce livestock diseases and mortality helping them cope with drought.

3.1.3. Creation of alternative livelihood

Creation of alternative livelihood in micro enterprises, commercializing aloe production, bee keeping (honey/wax production) and tourism activities will diversify income sources from livestock dependency and create additional demand for electricity. Though tourism potential is not well developed, improved tourism services will create direct and indirect[5] employment opportunities in restaurants, hotels, game reserves and national parks. Currently, 95% of people employed in the Lake Baringo and Bogoria reserves and conservancies are local and are paid from park revenue collection. About 6% of the revenue is given back to the community for development projects (2% of this goes towards bursary (payment of school fees for the most needy children) while 4% to projects (schools, water health facilities, e.g. maternity wing of Loboi health centre) (Amdany, personal communication, 2010).[6]

These will lead to attainment of MDG goal 1 on eradication of extreme poverty and hunger as well as goal 2 as it will enable more children go to school and also lead in general improvement of health (goal 4–6).

3.2. Goal 2: achieve universal primary education

Nationally, there is a wide disparity in education between pastoral nomads and the rest of Kenyans. In East Pokot, a large percentage of the population in the age group of >40 is either illiterate or semi-literate while most of the population below the age of 30 have attained at least primary school education. High level of school dropout is due to traditional and cultural practices and is higher among the pure pastoralist than the agro-pastoralists. The illiteracy rate is estimated in East Pokot to range between 85 and 95% [20]. Both boys and girls drop out of school prematurely in East Pokot. School dropout among the girls is caused by early or forced marriages on the outset of puberty, female genital mutilation (FGM) and domestic chores. The boys are expected to herd livestock and engage in cattle rustling after circumcision.

Since the study area is at the end of the power line, most of the schools do not have access to electricity and cannot be converted into boarding schools and the children neither have enough time to study in the evening either nor light. Use of kerosene and wood for lighting for studying increases health related problems.

Lack of electricity and access to radios and televisions coupled with inability to read has also led to lack of information among the adults. Geothermal development and accompanying infrastructure will improve access to such services; improve communication and awareness through radio on peace building, health and nutritional issues, etc. Education is a critical aspect to all the MDGs.

3.3. Goal 3: promote gender equality and empower women

Education plays a critical role in promoting equal opportunities between men and women. Women in the study area do almost 3/4 of the work, e.g. construction of houses, domestic work, milking, herding cows sometimes, fetching firewood and water, cooking, farming in irrigated areas and are mostly engaged in the care economy. Migration in search for pasture and water leaves women and children with additional work of tending to some small stocks and weaker animals in addition to walking over long distances in search of water and firewood. Drought and migration interferes with schooling of both boys and girls due to the fact that they have to assist in searching for pastures, water and firewood respectively.

Whereas men inherit land and animals, the women do not have assets and do not inherit or own land or livestock (except when given as gifts from parents). Women headed households are always viewed as the lowest of the low (including widows). Single women in market centres are more empowered than the rural women in male-headed households because they fend for themselves and are perceived as defiant. Women and children are treated the same way no matter how qualified and educated they are (Obiero, personal communications, 2010).

Gender disparity in the study area is brought about by culture and traditions, which define the roles and responsibilities

[5] GFD (General Food Distribution). This is a blanket provision of food to households in an area. The amount of food distributed is generally equal per household.

[6] The local community will tap from the main tourist activities through cultural exhibition, selling of curios, community camping sites.

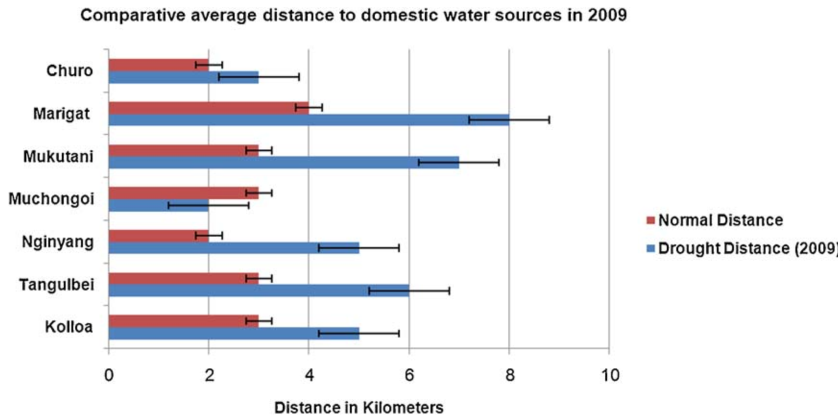

Fig. 7. Comparative average distance to domestic water sources in 2009 (Government of Kenya, 2009).

of women. This perception has been difficult to change due to isolation of the communities living in the study area from the rest of the country. The development of geothermal will open up the area and create avenue for new gender differentiated roles and improve access to information which will in-turn empower women and educate the men.

3.4. Goal 4: reduce child mortality rate

Recurrent drought, lack of adequate and vital foods, low immunization coverage, poverty, lack of education, poor sanitation, inadequate health facilities and medical personnel are the main barriers in combating child mortality and malnutrition levels in study area. For example, Vitamin A coverage in 2008 was 37% and declined to 4.1% in 2009 due to lack of outreach services and rural access. This is a major contributor to high morbidity among children under five [17]. Provision of electricity will in health facilities and close to the population will encourage use of better health equipments as well as cold chain for immunization and ultimately reduced child mortality.

The improvement in this MDG will also improve goal 1, 2, 3, 5, 6 and 8.

3.5. Goal 5: improve maternal health

Only 10% of women in the pastoral community deliver in health facilities due to lack of proper delivery facilities at the local health centres, long distances to health facilities with maternity (Marigat and Tenges hospitals) and high cost of delivering at nearby private hospital that charge KES 2500 per delivery [19].

The problem is exacerbated by lack of good infrastructure, which has led to low retention and attraction of health workers. In East Pokot for example, there is one district hospital with one doctor, three health centres and thirteen dispensaries. There is at least one nurse in each health facility, and five clinical officers [20]. The limited number of medical staff serves a population of >150,000 people in Nginyang', Kolloa and Tangulbei [21].

Improved access to electricity from geothermal development will have an impact on improved reproductive health facilities and equipments, which will have a significant contribution in reducing maternal mortality. Improved maternal health is also linked to reduced child mortality rate (goal 4).

Continued substitution of kerosene and wood fuel over time will reduce the level of exposure to indoor air-pollution, time and manual energy associated with collecting of firewood, which will in turn improve maternal health.

3.6. Goal 6: combat HIV/AIDs, malaria and other diseases

Poor nutrition increases vulnerability to HIV/AIDs upper respiratory tract infection (URTI), malaria, diarrhoea, skin infections and pneumonia which are prevalent in the area. The diseases lead to less productivity, increases the cost of medical care for the households resulting into a profound negative impact on household food security and reduces ability to fight malnutrition.

Unlike hydro, utilization of geothermal energy does not cause malaria, skin diseases, water borne diseases and water related disease due to the impounding of water [22]. However, with improved electrification and other infrastructural services, doctors will have electricity they need to treat patients 24 h a day, thus enabling easy and quick access to medical care.

3.7. Goal 7: ensure environmental sustainability

The main targets of this MDG are tied to reducing biodiversity loss, reduction by half the by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation.

3.7.1. Access to water

Kenya is below the international water scarcity threshold of 1000 m^3 per person per year [23] with only 935 m^3 available per person per year [24], and population growth is forecast to reduce this figure to 359 m^3 by 2020 [25]. The scarcity persists most times of the year leading to longer trekking distances, animal deaths, food shortages and poor health and sanitation.

In the study area, distance to water sources is dictated by availability of rain, proximity to permanent sources and can vary from a few meters to over 10 km. During the 2009 drought, the distance increased from the normal 2 to 3 km to 7 to 8 km in the agro-pastoral livelihood zones of Marigat, Mochongoi, and Tangulbei and from the normal 3 to 4 km to 8 to 10 km in the pastoral livelihood zones Kollowa, Nginyang, Tangulbei, Mukutani and Kabartonjo. The trekking distance to domestic and livestock water sources are illustrated in Figs. 7 and 8.

Water consumption averages 10–15 l per person per day in agro-pastoralist zones while households in pastoral livelihoods use the lowest quantity of water, 10 l per person per day on average [17]. Domestic water Deficit in Marigat is 40 m^3/day, Endao 21 m^3/day and Loboi 34 m^3/day. Livestock deficit in Marigat is 65 m^3/day, Ngambo 31 m^3/day, Endao 21 m^3/day and Eldume 3 m^3/day [26].

The distance is also determined by availability of boreholes, their functioning condition and water quality. The use of some of high yielding boreholes is limited by high sodium and fluoride content. The Catholic and Baptist churches are currently using bone pellets incinerated at a temperature of 500 °C to kill organic matter. The

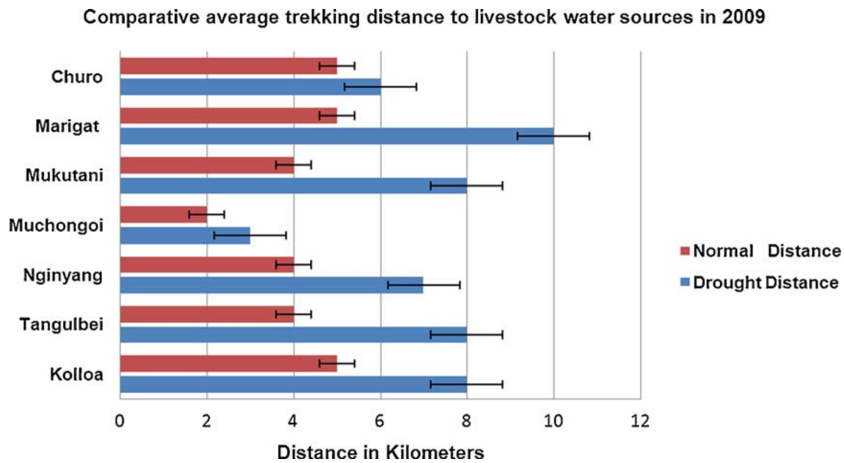

Fig. 8. Comparative average trekking distance to livestock water sources in 2009 (Government of Kenya, 2009).

calcium in the bone is used to act like a filter media to remove fluoride from the water. A series of calcium pellet tanks can remove fluoride from 24 ppm to 12 ppm and eventually to 0.5 ppm, e.g. Longewan in Marigat district (the use is limited to a few boreholes) (Rotich, personal communication, 2010).

Improved ground water lifting brought by improved access to electricity will improve access to clean and portable water for domestic and livestock consumption, reduce time spent on water collection by women and children, improve hygiene and sanitation, and create alternative livelihood through small scale irrigation. Lack of well developed water infrastructure in the study area has contributed to the significant livestock loss during droughts.

Water is a crucial resource in the area and will be required for development of geothermal energy especially drilling and other uses that may arise during construction and operation of the power plants. Drilling one geothermal well takes approximately 60 days and consumes 100,000 m^3 [18]. It is important to assess the potential and availability of water for geothermal use and community demand especially in areas where the water will have to be shared or new boreholes drilled. Water sharing arrangements with the community from drilled borehole will improve access to the limited resource. To sustainably utilise geothermal resources in the study area especially low temperature resources, maximum re-injection and use of geothermal brine for drilling should be mandatory.

Table 5
Summary of the impact of geothermal development on the MDGs.

	MDG	Current status	Role of geothermal
Goal 1	Eradicate extreme poverty and hunger	Poverty, recurrent droughts and conflicts. Dependency on food aid throughout the year	Geothermal would provide energy and electricity closer to the people and increase opportunity for income generating activities ultimately reducing dependency on food aid
Goal 2	Achieve universal primary education	Lack of energy for lighting in schools, homes and for modern learning equipments like computers and telecommunication equipments Early school dropout due to culture and poverty	Provide electricity in schools and homes where possible to reduce use of kerosene lamps which are associated with indoor air pollution Increase E learning, access more information even for teachers Provision of electricity will lead to increase in business which will improve affordability for secondary school fees, retention rate for school going children will ultimately increase
Goal 3	Promote gender quality and empower women	Pastoralist culture suppresses women. The male children have more opportunities than the female	Provision of energy will give rise to alternative income sources which will alleviate the pressure to marry girls at younger age for cash or animals Women will be able to generate additional income by engaging in small businesses
Goal 4–6	Reduce child mortality, improve maternal health, combat HIV/AIDs malaria and other diseases	Currently the unconnected hospitals use LPG, kerosene and charcoal. Distant medical facilities, inadequate equipment and staff	Geothermal will provide energy for health purposes, e.g. in government health facilities, for sterilization, immunization, health education, modern medical equipments and attract health personnel Geothermal in the area has the potential to provide remote health centres with decentralized systems Improve access to health information/education through broadcasting
Goal 7	Ensure environment sustainability	High dependency on wood fuel leading to environmental degradation, use of diesel generators causing pollution	At national level, it will reduce dependency on emergency power and imported fuels and use of kerosene for lighting Offset carbon emissions Improved access to water will lead to improved hygiene, reduce disease, create more time for men, women and children to engage in productive uses It will also reduce the risk of biodiversity loss through over exploitation of trees and woody plants
Goal 8	Develop a global partnership for development	Very low interactions	Geothermal contribution through capacity building, technology transfer, financing, including trade in CDM

3.7.2. Impact on biodiversity

Geothermal development is known to co-exist with wildlife, e.g. Olkaria geothermal development in Hellsgate but a clear environmental management plan must be developed between developer and park management. Due to the rich birdlife in Lake Baringo and Bogoria, precaution should be taken when laying transmission lines to avoid bird flight/migratory paths. Cabling should be done where necessary. Since the region has very little vegetation, no impact on vegetation is expected.

3.8. Goal 8: develop a global partnership for development

This MDG mainly focuses on the different roles and responsibilities between developed and developing countries in the attainment of the MDGs. The relevance to geothermal can be through bilateral and institutional cooperation in capacity building, technology transfer, financing as well as international trading in carbon offset from geothermal development through clean development mechanism (CDM). Geothermal development within the Eastern Africa Rift Valley will lead to increase in the number CDM projects in Africa which has the least.

3.8.1. Summary of impact of geothermal development on MDGs in the area

All the MDGs are interrelated with gain on one having a cumulative impact on the rest. Summary of impacts of geothermal development on MDGs is in Table 5.

4. Discussions and conclusions

Availability and development of high potential geothermal resources in remote areas of the study area, which had been condemned as inaccessible due to distant location from current modes of power generation will have a significant positive impact on the local people in terms of access to electricity, sustainable development and steps towards the MDGs.

Less than 1% of the households in the study area have access to electricity despite the high potential in geothermal, wind and solar energy. The connected households are concentrates in the market centres and are mostly government and institutional workers and a few businessmen. Though affordability and accessibility have played a key role in access to electricity in the region to some extent, lack of electricity infrastructure development by the government has significantly contributed to its use and availability thus slowing down the progress towards the attainment of the MDGs. Recent deregulation of the power sector has led to improved development planning with different players, accelerating development of electricity.

Decentralised or off-grid electrification in form of minigrids and isolated systems that are not connected to the national interconnected grid system can provide an alternative solution at lower costs than grid extension and have significant social and economic impact on the region as well as on the MDGs. Electrification improve lighting, rural services, tourism, informal and cottage industries. Adoption of electricity for cooking might be slow due to cultural and economic factors.

International cooperation in technology transfer and financing of geothermal development is required to improve access to geothermal development for economic development and to meet the MDGs. The planned accelerated geothermal development in the region will certainly open it up for investments and local wealth creation. Development of geothermal alone will not lead to attainment of MDGs without integrated planning by relevant institutions and government ministries in supporting and improving infrastructure like schools, hospitals, etc. Technical, institutional and financial investments will therefore be required to spin off progress to the MDGs since the region is way behind in comparison to other regions in Kenya.

Development of geothermal energy should not limit research and development of other renewable forms of energy like solar, wind and biogas where feasible.

'*Let there be light*'

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